

AD/RHIC/AP-99

RHIC PROJECT
Brookhaven National Laboratory

**Comparison of Aperture Determinations for
RHIC 91 and RHIC 92 at $\beta^* = 6$ m**

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1. Introduction

Tracking studies on RHIC92 have consistently shown an aperture that is 1-2 mm smaller than that obtained for RHIC91. RHIC92 has an extra dipole, D8, in every half insertion. Since assignment of randomly generated multipoles is made sequentially, the default multipole assignments for the two lattices are different and thus complicate comparison of results. Comparison of the two lattices using the same multipole assignments can be made in two ways: 1) by making all D8 dipoles perfect to force RHIC92 to have the same multipole assignment as RHIC91 in all quadrupoles and dipoles, other than D8; and 2) by forcing RHIC91 to have the same multipole assignments as the corresponding elements in RHIC92 by generating the error distribution for multipole elements, having the null set $(\sigma a_n, \sigma b_n) = (0, 0)$ of rms errors, inserted at the location of the D8 dipoles between all Q8 and Q9 quadrupoles.

The present study was made for DX and DO dipoles having coil i.d.'s of 20 cm and 10 cm, respectively. The inner radius of the vacuum chamber was 96.0 mm in DX, 46.0 mm in DO, and 58.8 mm in the Q1-Q3 triplet.¹ Tracking was performed using ten sets of randomly generated multipoles corresponding to ten seeds used to initialize the random number generator. Particles were launched with $\epsilon_{i(x)} = \epsilon_{i(y)}$ and $X'_i = Y'_i = 0$ when $\Delta P/P = 0\%$. Tests on particle amplitude were made in every element to assure the particle stayed within the vacuum chamber. The results are shown in terms of the initial amplitude X_i at a point where $\beta_x = 50$ m. Results of aperture determinations are presented as histograms in Figure 1. The numbers in the boxes comprising the histogram indicate

the seed used for measurement; the width of the box indicates the amplitudes at which the particle survived (left side) and failed within 1000 turns (right side).

2. Results

A. RHIC92 having randomly generated multipoles in all dipoles and quads. The ten sets of randomly generated multipoles obtained using the element sequence of the RHIC92 lattice are denoted by the terms “92” sets. Figure 1(a) shows aperture determinations for the ten seeds. Seed #9 resulted in the worst case scenario – the test particle survived when $X_i = 16.0$ mm and failed when $X_i = 16.8$ mm. The average value of X_i is 16.4 mm for $\Delta X_i = 0.8$ mm ($X_i = 16.6$ mm when a finer mesh of $\Delta X_i = 0.4$ mm was used). This agrees well with Parzen’s value of 16.5 mm for the aperture of RHIC92 at $\beta^* = 6$ m when dipole DX has a 10 cm coil i.d.²

B. RHIC92 having the “92” sets of randomly generated multipoles in all quadrupoles and all dipoles but D8. In this case, the D8 dipoles are made “perfect” by assigning the null set $(\sigma a_n, \sigma b_n) = (0, 0)$ to multipole elements at the D8 dipoles. Figure 1(b) shows the worst case scenario is again represented by seed #9. The test particle survived at $X_i = 17.6$ mm and failed within 1000 turns at $X_i = 18.4$ mm. The bin average, $X_i = 18.0$ mm, is used as the aperture.

C. RHIC91 having the “92” sets of randomly generated multipoles in all dipoles and quads. The multipole sequence throughout the lattice is maintained by inserting multipole elements, associated with the null set of $(\sigma a_n, \sigma b_n)$, at a location between Q8 and Q9 quadrupoles. Figure 1(c) shows the worst case scenario is represented by seeds #1 and #8. The test particles survive at $X_i = 17.6$ mm and fail at 18.4 mm. The aperture quoted is 18.0 mm. The maximum for the distribution of Figure 1(c) is one bin higher than the maxima of Figures 1(a) and 1(b); this is characteristic of the differences between RHIC92 and RHIC91.

D. RHIC91 having the “91” sets of randomly generated multipoles in all dipoles and quads. The results for RHIC91 are shown in Figure 1(d). The worst case scenario results from seed #4 and again gives survival when $X_i = 17.6$ mm and failure when $X_i = 18.4$

mm. The aperture is $X_i = 18.0$ mm for $\Delta X = 0.8$ mm ($X_i = 18.2$ mm when $\Delta X_i = 0.4$ mm). This is 0.7 mm larger than Parzen's value of 17.5 mm.² The maximum of the distribution of Figure 1(d) occurs at the same amplitude as that of Figure 1(c) and supports the claim that RHIC91 has a slightly larger aperture than RHIC92.

3. Summary

Part of the motivation for this study was to explore the possibility that RHIC92 is particularly sensitive to nonlinear fields at the location of the D8 dipoles. Comparing the results for Figures 1(a) and 1(b), it is seen that, when multipoles were removed from the D8 dipoles, the aperture decreased by one bin for one seed, remained unchanged for four seeds, increased by one bin for four seeds, and increased by two bins for one seed. The average for the distribution increased by only half a bin and seems to discount the possibility that RHIC92 is particularly sensitive to nonlinear fields at the location of the D8 dipoles.

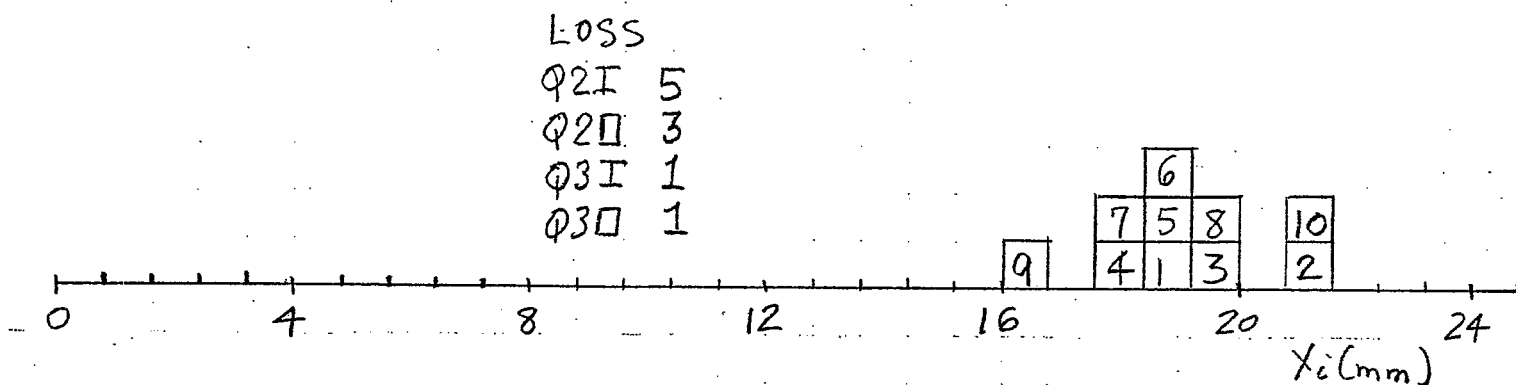
Figures 1(a) and 1(b) indicate all test particles were lost in the Q2 and Q3 quadrupoles for RHIC92 and all but one were lost in Q2 and Q3 for RHIC91. Thus the DO dipoles are no longer the aperture limiting elements.

The peak values of the histograms for RHIC91 are consistently one bin higher for RHIC91 than they are for RHIC92 and are consistent with an aperture difference of $\Delta X_i = 0.8 \pm 0.8$ mm.

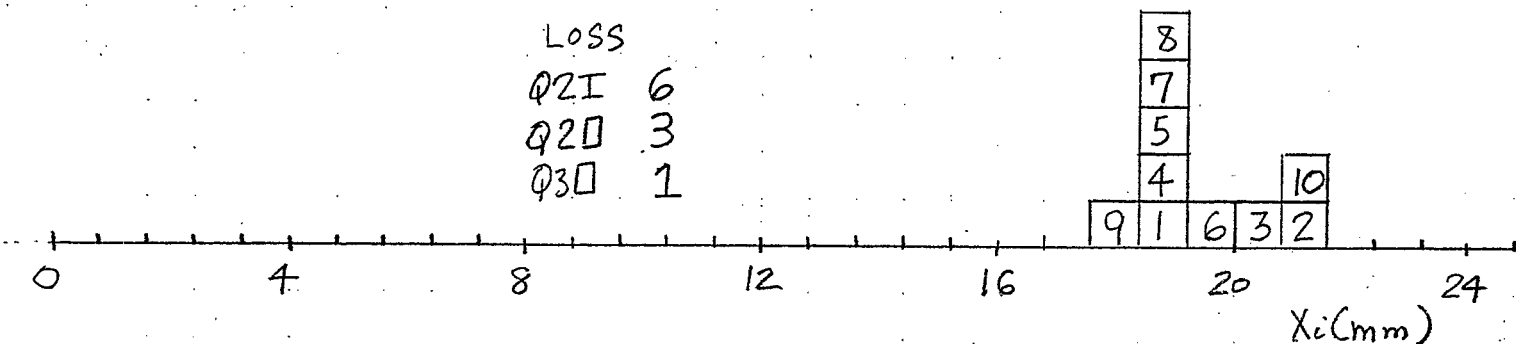
References

1. P.A. Thompson, private communication concerning the wall thickness of the vacuum chamber in Q1-Q3, July 1, 1991.
2. G. Parzen, Memo to M. Harrison, March 31, 1992.

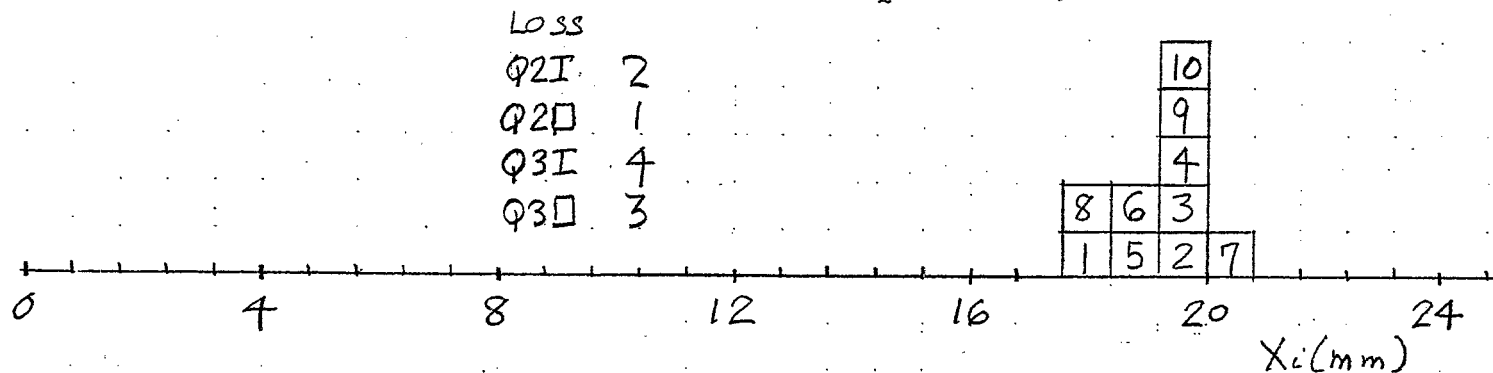
a). RHIC92: "92" MULTIPOLE SETS IN ALL DIPOLES AND QUADRUPOLES.



b). RHIC92: "92" MULTIPOLE SETS IN ALL QUADRUPOLES AND ALL DIPOLES BUT D8.



c). RHIC91: "92" MULTIPOLE SETS IN ALL DIPOLES AND QUADRUPOLES.



d). RHIC91: "91" MULTIPOLE SETS IN ALL DIPOLES AND QUADRUPOLES.

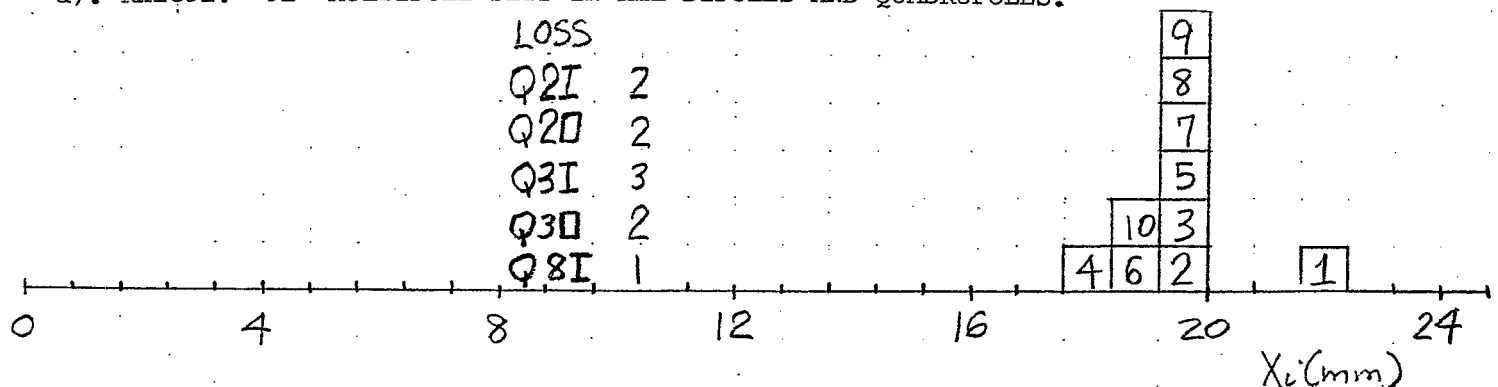


FIGURE 1. DISTRIBUTION OF RHIC92 AND RHIC91 APERTURE DETERMINATIONS FOR SEVERAL MULTIPOLE CONFIGURATIONS.